DOCTOR
OF
PHILOSOPHY

SPRAY GENERATION FROM LIQUID WALL JETS
OVER SMOOTH AND ROUGH SURFACES

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This is an experimental investigation of the filaments and drops generated at the free surface of liquid wall jets formed over smooth- and sand-roughened surfaces. The jet characteristics and the geometric properties of the filaments and drops were measured from images captured using high-speed digital cameras. A statistical investigation of the various properties revealed the characteristic behavior of the filaments and drops as a function of the relative wall roughness, wall curvature and jet inertia. For this investigation, the wall jet Reynolds number ranged from 2.6×10^4 to 4.5×10^4, the Froude number from 19 to 33 and the Weber number from 1600 to 4700.

The emphasis herein was on the physics of the process rather than the development of empirical relationships. As such, the results indicate that spray generation from a wall jet is a boundary-layer-driven phenomenon, requiring that the jet be in a highly supercritical state (Fr » 1). Wall roughness reduces the minimum necessary level of supercriticality, but it is not a prerequisite condition for the formation of drops. While increasing the jet inertia enhances the drop formation process, concave wall curvature tends to reduce the quantity and the energy of the drop forming events.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Spray, Drops, Jets, Bow Sheets, Turbulent Boundary Layers, Liquid Sheets

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AN EXPERIMENTAL INVESTIGATION OF VORTEX BREAKDOWN IN TUBES AT HIGH REYNOLDS NUMBERS
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This thesis deals with non-cavitating swirling flows with vortex breakdown in various tubes. Phenomenological and quantitative investigations were carried out at Reynolds numbers ($Re_D = U_0D_0/\nu$) as high as 300,000. It was shown that a high Re_D vortex transitions to its new state (breaks down) via a rapidly spinning spiral form, as demonstrated with 4,000 frame per second video, short exposure time (6 ns) imaging, and Digital Particle Image Velocimetry. Of the known types, the spiral emerges as the fundamental breakdown form, and the axisymmetric bubble may now be regarded as a relatively low Re_D occurrence that is bypassed at sufficiently high Re_D. Some new phenomena were observed at high Re_D: Extremely rapid spiral rotation (over 1,000 revolutions per second), core bifurcation, and reversals in the sense of the spiral windings. Familiar features of breakdowns, such as the transition from jet-like to wake-like axial velocity profiles and the rapidly expanding vortex core, were observed in extensive time averaged velocity and turbulence profiles ascertained with Laser Doppler Velocimetry. However, a mean stagnation point and recirculation were absent in the highest Re_D flow. The core meandering and stagnation point darting in the turbulent flow field were quantified and discussed in detail.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Vortex Breakdown, Turbulence, Laser Doppler Velocimetry, Particle Image Velocimetry, Swirling Flow, Spectra

AUDITORY-VISUAL CROSS-MODAL PERCEPTION PHENOMENA
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The quality of realism in virtual environments is typically considered to be a function of visual and audio fidelity mutually exclusive of each other. However, the virtual environment participant, being human, is multi-modal by nature. Therefore, in order to more accurately validate the levels of auditory and visual fidelity required in a virtual environment, a better understanding is needed of the intersensory or cross-modal effects between the auditory and visual sense modalities.

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To identify whether any pertinent auditory-visual cross-modal perception phenomena exist, 108 subjects participated in three main experiments which were completely automated using HTML, Java, and JavaScript computer programming languages. Visual and auditory display quality perception were measured intramodally and intermodally by manipulating visual display pixel resolution and Gaussian white noise level and by manipulating auditory display sampling frequency and Gaussian white noise level.

Statistically significant results indicate that 1) medium or high-quality auditory displays coupled with high-quality visual displays increase the quality perception of the visual displays relative to the evaluation of the visual display alone, and 2) low-quality auditory displays coupled with high-quality visual displays decrease the quality perception of the auditory displays relative to the evaluation of the auditory display alone. These findings strongly suggest that the quality of realism in virtual environments must be a function of both auditory and visual display fidelities inclusive of each other.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual Environment, Auditory Display, Visual Display, Perception, Cross Modal, Fidelity, Experimental Design

SOLUTION OF LARGE-SCALE ALLOCATION PROBLEMS WITH PARTIALLY OBSERVABLE OUTCOMES

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Methods were developed for optimally solving problems that require allocating scarce resources among activities that either gather information on a set of objects or take actions to change their status. Also, the information gathered on the outcomes of the actions taken may be erroneous. The latter situation is called *partial observability*, and methodology available prior to this dissertation is combinatorially intractable for problems with more than one object. Two previously-uncombined methods were used–linear programming (LP) and partially observable Markov decision processes (POMDPs) – to construct a decomposition procedure to solve the resulting large-scale allocation problem with partially observable outcomes. Theoretically it was shown that this procedure is both optimal and finite; in addition, improvements were developedto the procedure that reduce runtimes on test problems by 95%. It was demonstrated that the procedure on a small targeting problem with a known analytical solution, as well as a large-scale military example concerned with allocating aircraft sorties, weapons, and bomb-damage assessment sensors to targets. Finally, analytical bounds were developed on the expected objective function values of a related allocation problem with more stringent resource constraints, and present a simulation-based approach to estimate the distributions of the outcomes for that model.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control, and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Materials, Processes, and Structures

KEYWORDS: POMDP, MDP, Linear Programming, USAF, BDA, Sensor Modeling